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0406730.2

2. Patent application number *(The Patent Office will fill in this part)* — 25 MAR 2004

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

1... Limited
St John's Innovation Centre
Cowley Road
Cambridge CB4 0WS

Patents ADP number *(if you know it)* — 81138 70001

If the applicant is a corporate body, give the country/state of its incorporation — England

4. Title of the invention — FOCUSSING METHOD

5. Name of your agent *(If you have one)* — Ursula Lenel

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* — YES
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Claim *(s)*	1
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11. I/We request the grant of a patent on the basis of this application.

Signature *Ursula Lenel* Date 25 Mar 2004

12. Name and daytime telephone number of person to contact in the United Kingdom Ursula Lenel 01223-422290

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P180-GB

FOCUSSING METHOD

FIELD OF THE INVENTION

This invention relates to optical imaging apparatus such as digital cameras. More particularly, it relates to miniature cameras for use in portable electronic equipment such as mobile telephones, Personal Digital Assistants (PDA), portable computers, digital stills cameras and the like.

BACKGROUND OF THE INVENTION

Many digital cameras are furnished with an autofocus facility. Typically, in conventional autofocus methods an actuator moves a lens and a sample image is captured at several lens positions. The sample image usually covers only a small area of the picture, typically the centre. The data representing the sample image is then processed according to an autofocus algorithm, which compares the sample images to determine which of the lens positions provides the best focussed image (e.g. which provides maximum contrast between neighbouring pixels). The actuator then moves the lens to that position so that a focussed photograph can be taken.

These autofocus methods require an actuator to move the lens, firstly through the range of possible focus positions and then to the precise position corresponding to the best-focus position for image capture. The actuator is necessarily a precision device of some complexity, typically an electromechanical actuator such as an electromagnetic motor, for example a stepper motor, or a piezoelectric actuator. Such precision motors and actuators are relatively costly to manufacture. In addition, the actuator adds significant bulk and mass to the camera, which is undesirable in portable devices such as mobile phones. Further, actuators draw power during operation, using up battery life.

It is therefore the purpose of the invention to provide an improved autofocus mechanism in miniature cameras, which mechanism is less complex, less bulky, less costly and less power consuming than the known autofocus mechanisms.

classic "dash-pot" using a viscous liquid, or more preferably could be a lossy/ mechanically resistive plastic material. More preferably still, the return spring and damper can be fabricated from one and the same plastic moulding (possibly multi-shot) by suitable choice of geometry and material(s) combination. This provision of automatic return mechanism removes operator dependency from the lens dynamics during the picture-capture sequence. Lens travel is therefore known and repeatable so that timings of image capture (lens position) can be accurately pre-selected.

In a variant of the invention, an optical sensor senses dark and light marks on the lens barrel assembly, such optical marks representing positions (or transition points between positions) of various focus positions at which it is desired to capture the sequence of images. The signals from the optical sensor then may be used to trigger the image capture process, independently of any reliance on actuator motion, accuracy or repeatability, or of lens velocity during the sequence.

The mechanical linkage may be of any suitable form. Preferably it comprises one or a few components formed as plastic mouldings.

Note that in the above, the terms 'shutter button' and 'shutter release button' refer to the device the user activates to capture an image. However, in general in digital cameras there is no mechanical "shutter" and this terminology simply refers to the previous functionality of film cameras.

The mechanically driven focus mechanism described above refers to digital cameras (i.e. not to conventional film cameras). Whilst it may be used in any size of digital camera, preferably the digital camera is a miniature one, that is, one in which the lens diameter is a few millimetres, say in the range 2mm to 20 mm. At this small size, the mechanical load on the linkage is slight, as the mass of the lens elements is small (a few grams or less) so that depression of the button by the user is straightforward, that is, depression of the button does not meet with great resistance and can be engineered to have a good 'feel' to the user.

As described above, a series of images is captured at a number of lens positions. The greater the number of positions, the better approximation to perfect focus achievable.

For some applications, 2 or 3 lens positions suffice to provide one image approximately in focus. For best focus when used with high resolution image sensors, say 3 megapixel or more, better results are obtained when more lens positions are used, say 10 or more. In practice, capturing images at 5-7 lens positions generally provides one image which is adequately focussed.

In a first embodiment, the images taken at the series of lens positions are stored in their entirety for subsequent comparison and processing. Typical memory requirements are of the order of 3X MB for an image at X megapixel resolution e.g. a single frame of a 3 megapixel camera requires ~9 MB of storage space. However, alternative formats and compressions are available which reduce the memory required to the order of 1-2 megapixel for a 3 megapixel camera. Thus sufficient temporary memory must be provided to allow storage of a number, say 6, of such images. The autofocus algorithm is then applied to each image, or a part (say the central part) of each image, to allow the best focussed image to be selected. This image is then available for display and further storage, while the remaining images can be erased, freeing up the memory, or simply overwritten when the memory is next required.

In a second embodiment, the images are processed in real time. That is, a first image is captured and stored and a second image is captured and compared to the first image. The less good (least in focus) of the two images is discarded (or subsequently overwritten in memory) and the better image retained in storage. A third image is then captured (using whatever memory is free, e.g. the location of a previously discarded image) and compared to the stored image, and as before one image is discarded and the better one retained. This is repeated until all the preprogrammed lens positions have been passed. The remaining stored image then provides the best-focussed image. This embodiment requires less memory than the first embodiment above, since only one to two images are stored at any one time (rather than 6 or more), but needs potentially high speed processing, or at least, real-time processing in the sense that one image must be fully best-focus-processed before the start of the readout of the next from the image sensor into memory. Typical frame rates in digital cameras are 30 per second, in which case the time available for image comparison is of the order of 33 ms. The comparisons may be made between entire images, or between a smaller area (for example, the central area) of each image.

In a third embodiment, the final image is synthesised as a composite of images taken at several lens positions. Again, a complete frame is captured at each lens position. The image is divided into a number of regions (areas), and for each region, the best in-focus image of that region is selected. Thus image sub-areas of neighbouring regions may originate from separately exposed images captured at different lens positions, allowing all areas of the picture to appear in focus. This vastly increases the apparent depth-of-field of the camera. As before, the series of images may be stored in its entirety and subsequently processed, or each image may be compared to a single stored image (the currently best-focussed possibly composite image) in real time. In this embodiment, the comparisons are made on a region-by-region basis. For best effect, the size of the regions needs to be relatively small and the number of lens positions relatively large. Simulations indicate that for a 3 megapixel sensor, a high quality picture can be obtained with between 9 and 25 regions of roughly equal area and between 3 and 10 lens positions. In a refinement of this embodiment, the region boundaries are chosen to be "ragged" rather than long straight lines, and may usefully have a dominantly hexagonal perimeter rather than rectangular, as both these features make the region boundaries far less noticeable to the human vision system

In a further embodiment of this last described composite-image-best-focus scheme, there are no pre-defined image regions. Rather, the on-the-fly (or post image capture) image processing, for each captured image after the first, assesses pixel by pixel whether the newly captured image's pixel is part of a better-focussed sub-image of the scene, and if so, stores the new pixel value instead of the old. If the process determines that the newly captured image's pixel is not better focussed, the corresponding current-best-focussed image's pixel is retained and the new pixel discarded. The great advantage of this scheme over the previously described process, is that there are no artificially introduced region-boundaries in the final composite image, across which boundaries significant focus error will in general be visible. Instead, this process effectively makes every pixel a region in its own so the resultant composite will have no region boundaries visible whatsoever.

As described above, the autofocus operation may be linked to depression of the shutter release button, that is, the autofocus operation occurs when the user takes a

photograph. In a further embodiment, the autofocus operation can be caused to occur at other times also. This is useful if the user wants to view an in-focus image on the camera's display screen before taking a photograph. For this purpose, a focus button can be provided in addition to the shutter release button. Alternatively, the shutter release button can be arranged to trigger the autofocus operation separately from the photograph-taking operation. However, since at a minimum, to be useful an autofocus operation will either capture and store a focussed image, or, capture and display a focussed image, or both, it can be equally useful to simply provide for two modes of camera operation; in mode 1, depression of the shutter release button causes the entire multi-image capture, focus selection process, and final best-focussed image display only (with an option to subsequently store more permanently that displayed image); and in mode 2, all of the mode 1 operations occur with the best-focussed image automatically being transferred to more permanent storage. So Mode 1 is a "look and see" mode, while mode 2 is most similar to conventional point-and-shoot. Alternatively, the shutter release button can be designed such that the first part of the button's travel causes the autofocus mechanism to operate and the second part of the button's travel causes a 'photograph' to be taken. Thus the first part results in an in-focus image being displayed but not stored as a photograph, while in the second part, the in-focus image is both displayed and stored.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1A, 1B and 1C are schematic representations of an embodiment of the camera of the invention as part of a mobile phone.

DETAILED DESCRIPTION

Figures 1A-1C show an embodiment of the invention in which a mechanical linkage moves a lens element of a camera in a mobile phone.

Figure 1A is a front view of a mobile phone 1 showing a keypad 2, a display screen 3 and a shutter release button 4. Figure 1B is a perspective view of the back of the mobile phone 1 showing a miniature camera 5 including the lens assembly 6. Shown schematically with dotted lines are the housing of the camera 7 and the display screen 3, shutter release button 4 and a mechanical linkage 8 connecting the shutter release button and a part of the camera 5.

A simplified schematic cross section along the line AA' of Figure 1B is shown in Figure 1C (somewhat magnified compared to figures 1A and 1B). The mobile phone 1 includes the shutter release button 4 on the front of the phone and the camera 5 on the back. The camera 5 includes a housing 7, a sensor 11 and a lens assembly 6 incorporating a fixed lens 9 and a movable lens 10. (For clarity, the fixed and movable parts of the lens assembly are depicted as simple lenses; in reality they are generally lens groups). The shutter release button 4 is connected to the movable lens 10 by a mechanical linkage 8 which is in this case a simple rod. On depression of the shutter release button 4 by the user, the button 4 moves to the position shown by dotted lines 4a, the linkage 8 moves accordingly and causes the movable lens 10 to move to the position indicated by dotted lines 10a.

As described above, during the movement of the lens 10 from its resting position to position 10a, a series of images is captured by the sensor 11. An autofocus algorithm selects the best in-focus image from this series, and this image is displayed on the display screen 3 and retained as the in-focus photograph.

As will be apparent to those skilled in the art, the linkage 8 may be readily adapted to connect a shutter release button and a lens element whatever their positions in the phone, and further, may be designed with known techniques to produce the desired extent and speed profile of movement of the lens element 10. Similarly, return of the lens element to its starting position may be readily incorporated. All such designs are included in the scope of the invention.

CLAIMS

1. A digital camera including a button operable by a user, a lens element movable to alter the focal length of the lens assembly, and a mechanical linkage connecting said button to said lens element, wherein the mechanical linkage is adapted to move the lens element when the button is depressed by the user.

2. An autofocus method for a digital camera wherein a series of images at a series of lens positions is captured, an autofocus algorithm is used to determine which of said captured images is best in-focus, and said best in-focus image is selected for display and/or retention.

3. An autofocus method for a digital camera wherein a series of images at a series of lens positions is captured, a composite in-focus image is synthesised from said series and said composite image is displayed and/or retained.

4. A digital camera according to Claim 1 wherein production of the best in-focus image is carried out by a method according to Claim 2 or Claim 3.

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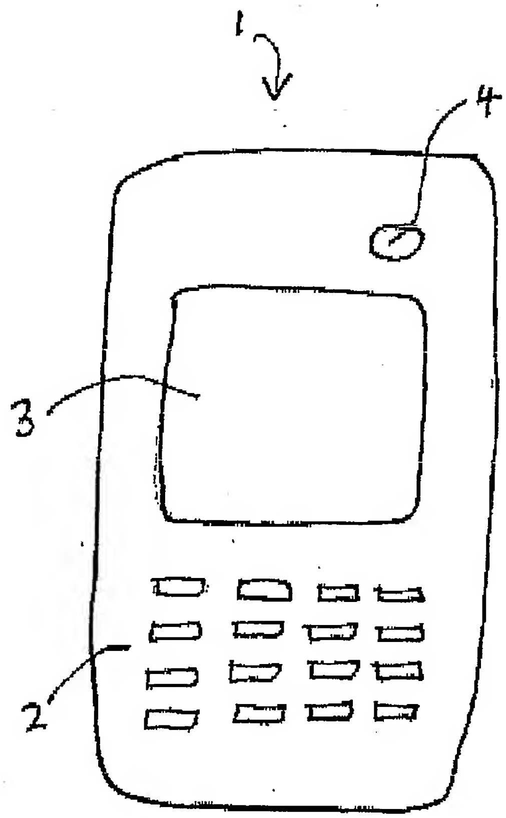

Figure 1A

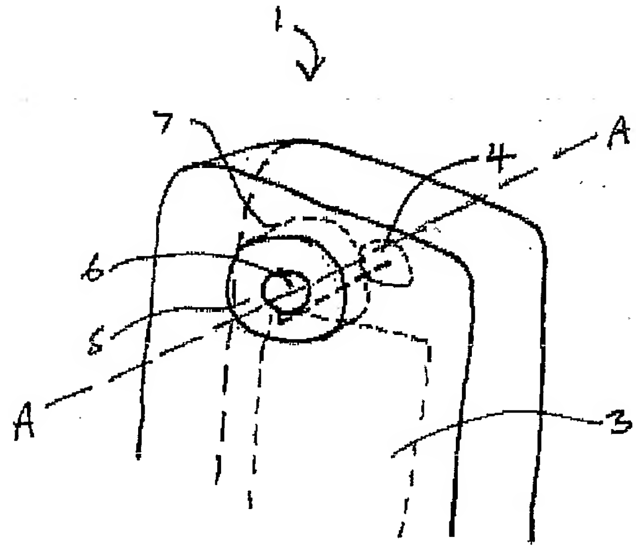

Figure 1B

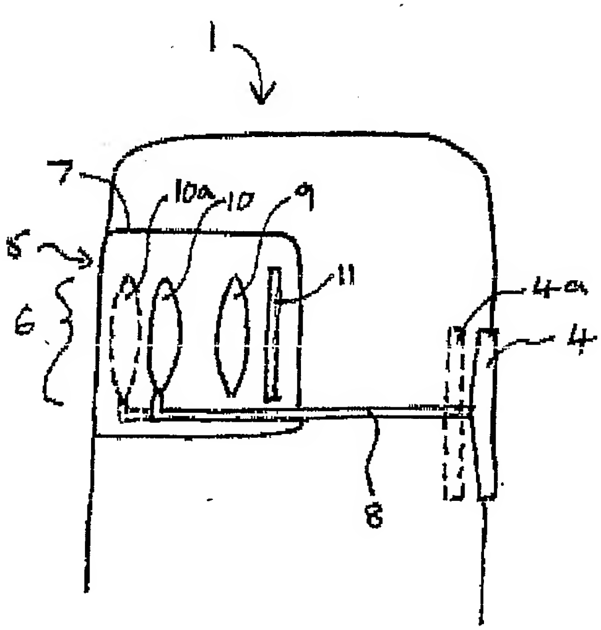

Figure 1C